Testing of a stacked core mirror for UV applications

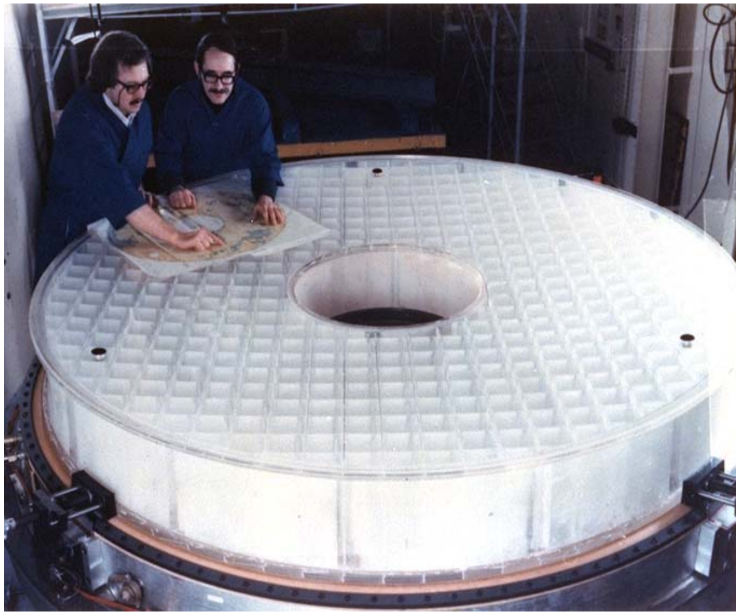
Gary W. Matthews, Charles S. Kirk, Steven P. Maffett and Calvin E. Abplanalp
Exelis Inc.

H. Philip Stahl, Ron Eng, William R. Arnold Sr.
NASA Marshall Space Flight Center

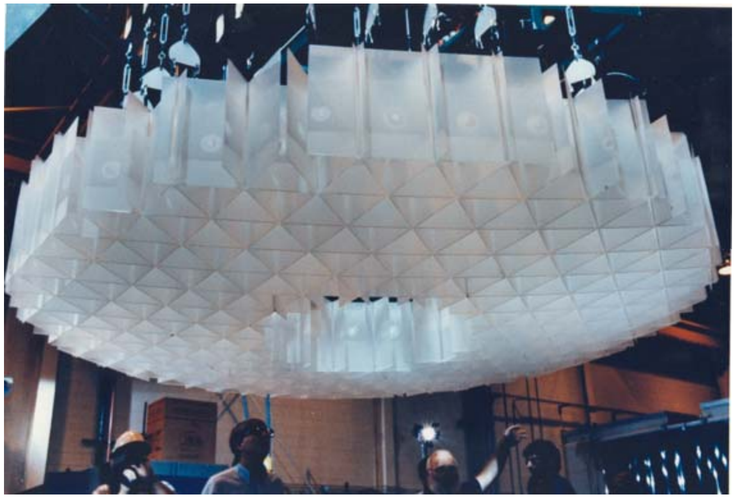
Advanced UVOIR Mirror Technology Development (AMTD) Program

- Develop mirror blank technology applicable to building a cost effective, large (4m-8m class), passive, monolithic mirror capable of imaging in the UV spectrum
  - 0.43m demonstration mirror fabricated
  - 5.5nm RMS overall surface figure demonstrated
- Current limitations regarding a 4m class mirror
  - Significant mirror depth required to achieve stiffness
  - Core depth drives up cutting costs, schedule, risk, and areal density
  - Stack sealing of boules to achieve overall depth is very expensive and time consuming
- AMTD program addresses these issues to reduce the cost and lead time for building a 4m class mirror blank and demonstrates the ability to polish and test the blank to UV quality

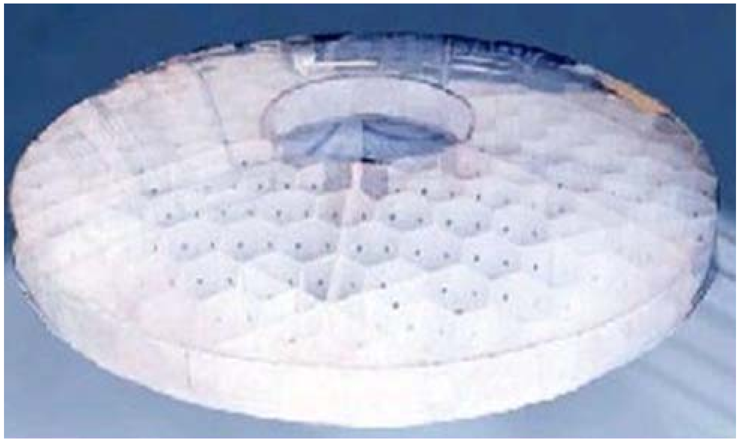
Large Lightweight ULE Primary Mirrors at Exelis



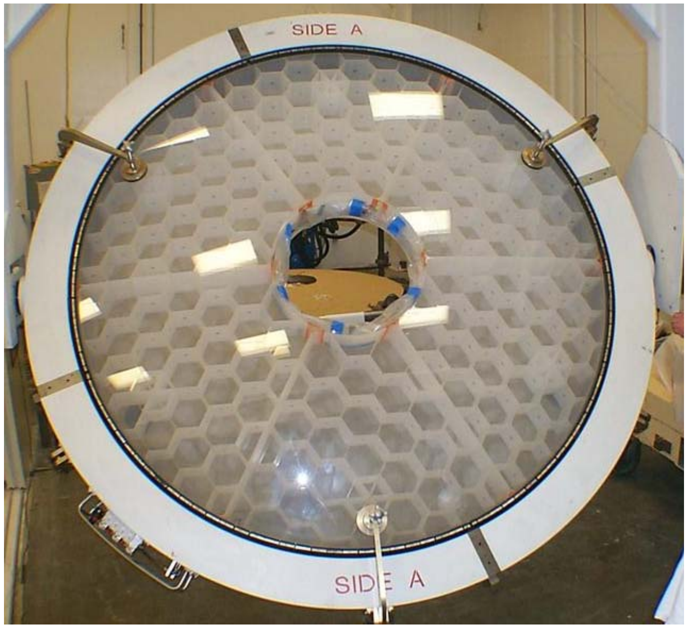
High Temperature Fusion – 1970's
(Hubble Primary Mirror)



Frit Technology with Flame Welded Core – 1980's

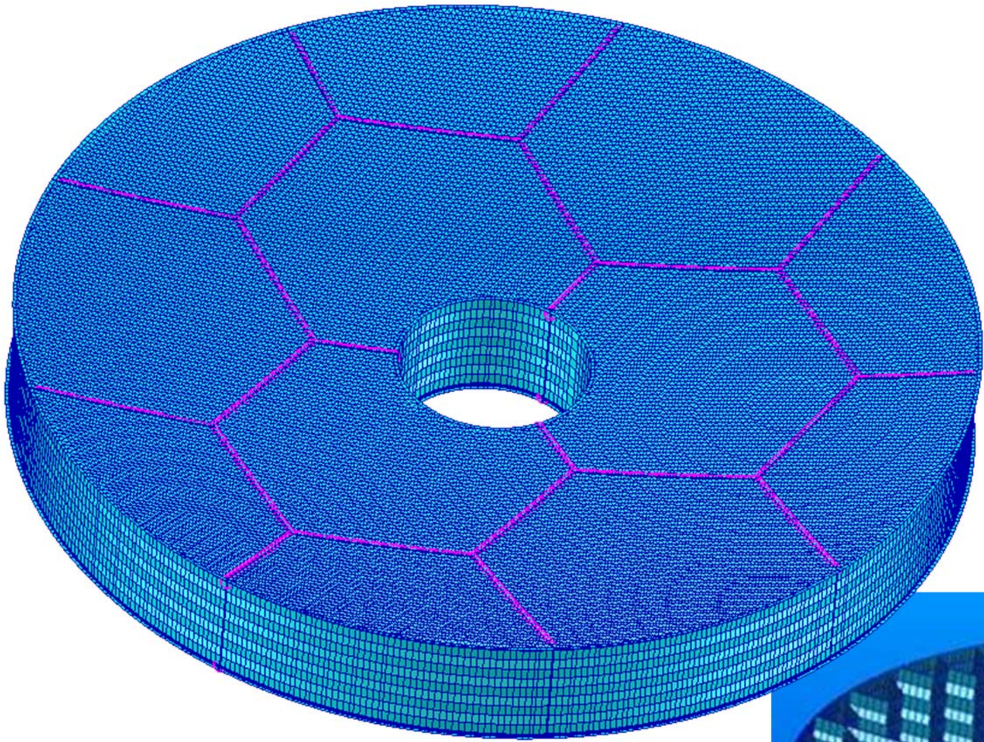


ATT – Waterjet Cut Core – Low Temp Fusion – 1990's



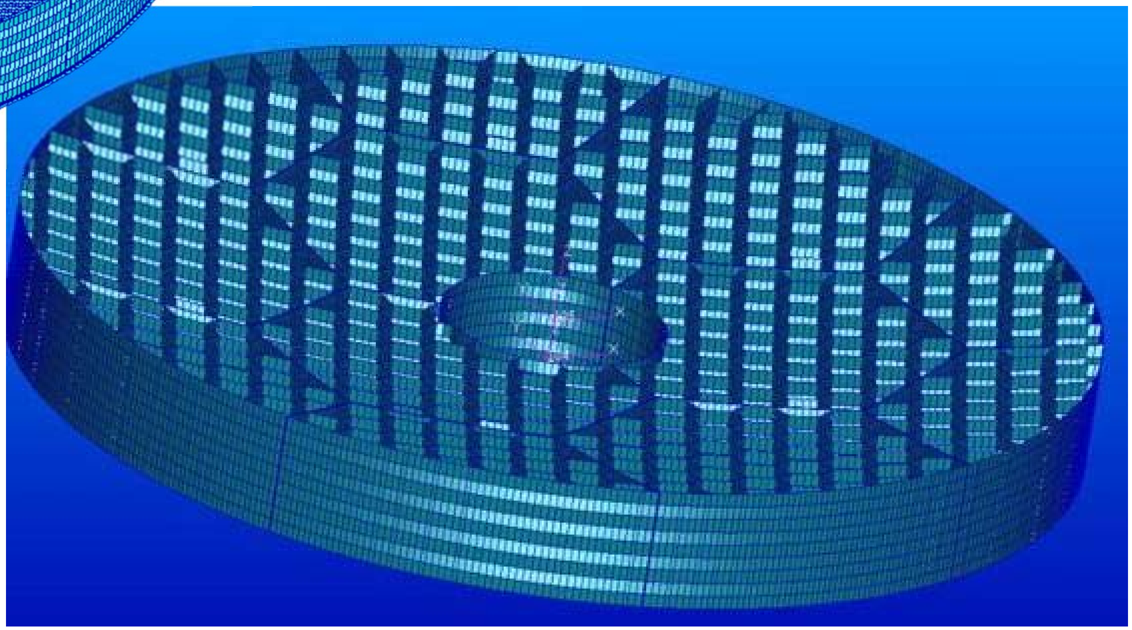
Primary Mirror – Low Temp Fusion – 2000's

4m Mirror Concept



4m Mirror Physical Attributes

- Pocket MilledFacesheet allows larger core cells while controlling quilting
- 12 Core Segments
- 3 Stacked Core Deep
- 10m RoC (F#1.25)



Efficient use of ULE Boules

- 27 boules to fabricate the 36 core segments
- 9 boules to fabricate the 2 faceplates (with spares)
- 36 flight boules

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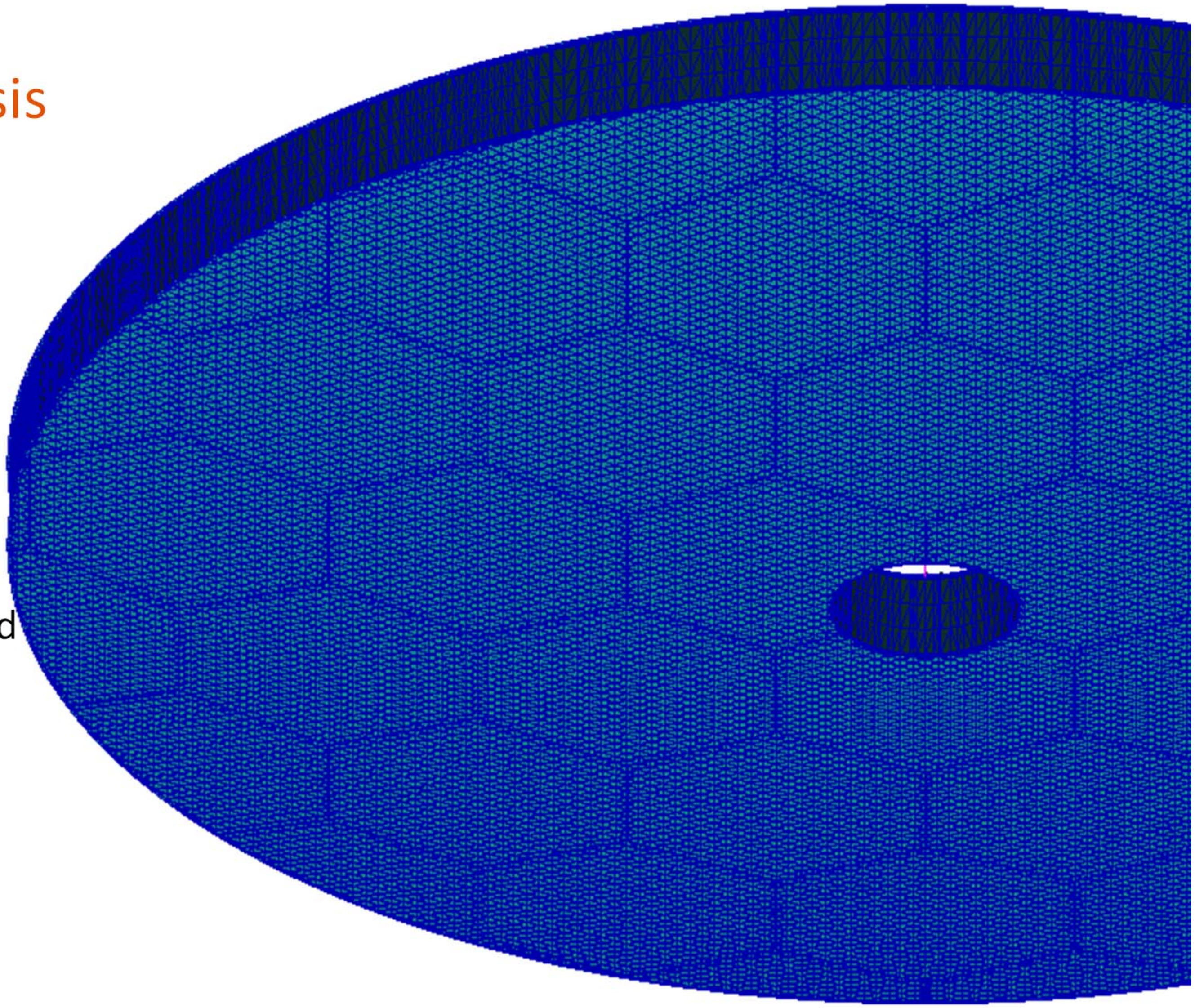
AMTD 8m Mirror Design and Analysis

- Stacked core and Pocket milled facesheet design
- 24.2m RoC (f#1.5)
- The 8 meter mirror modeled to assess performance
  - Model includes light-weighted face plates joined to a light-weighted core.
  - 5% additional mass added to light-weighted sections to account for corner radii.
- Total mass was 3042 kg, 60 kg/m^2
- First Free-Free mode at 33 Hz



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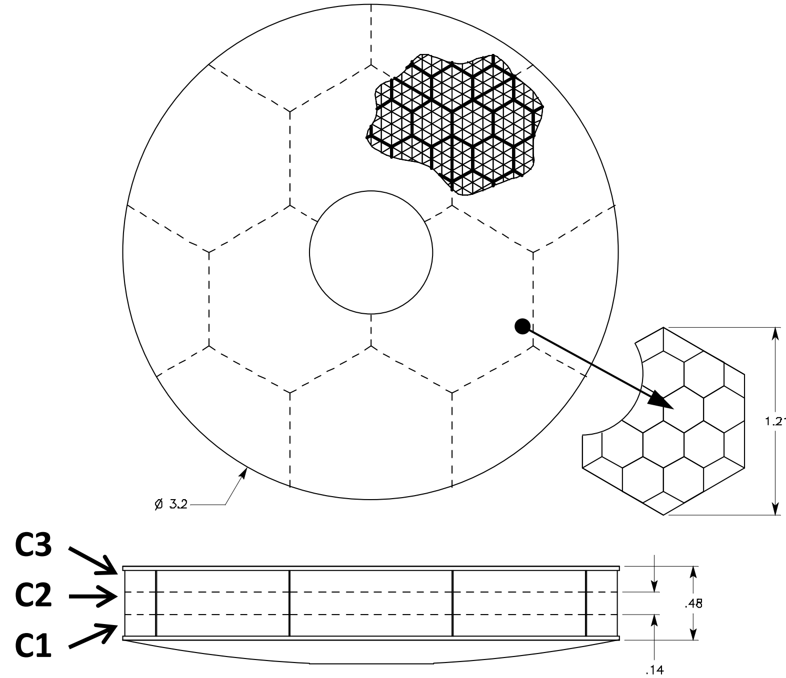
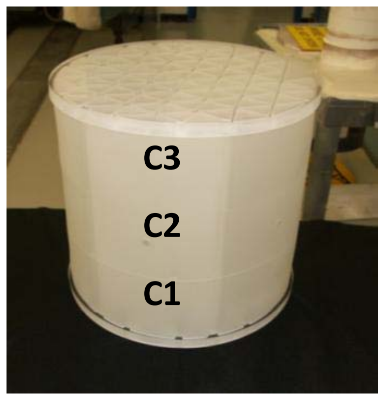
AMTD is Developing Technologies for Near Term Large Lightweight Primary Mirrors



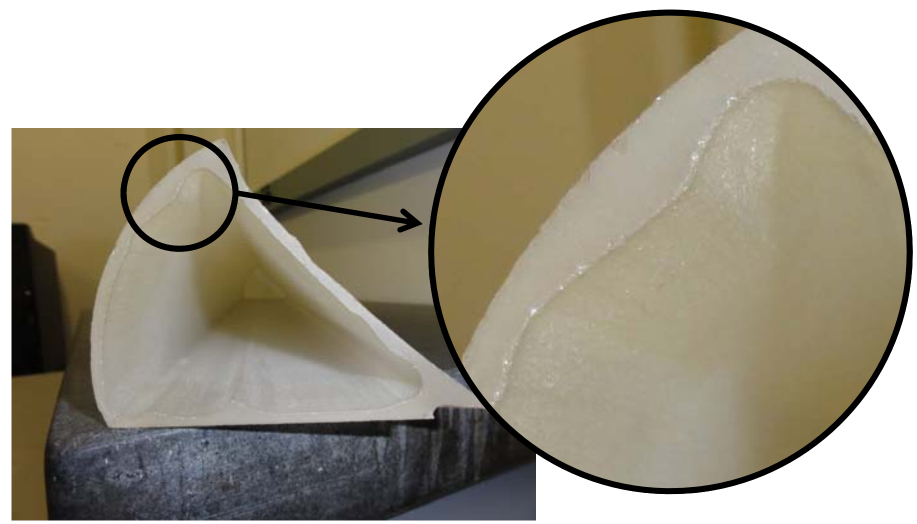
Stacked core

- > Core segments are fabricated from standard thickness boules, then stacked & fused during blank assembly to achieve a deep core
- > Eliminates need for stack sealing of boules and deep AWJ cutting of cores
- > Enables lighter weight cores and reduces cost & schedule for blank fab



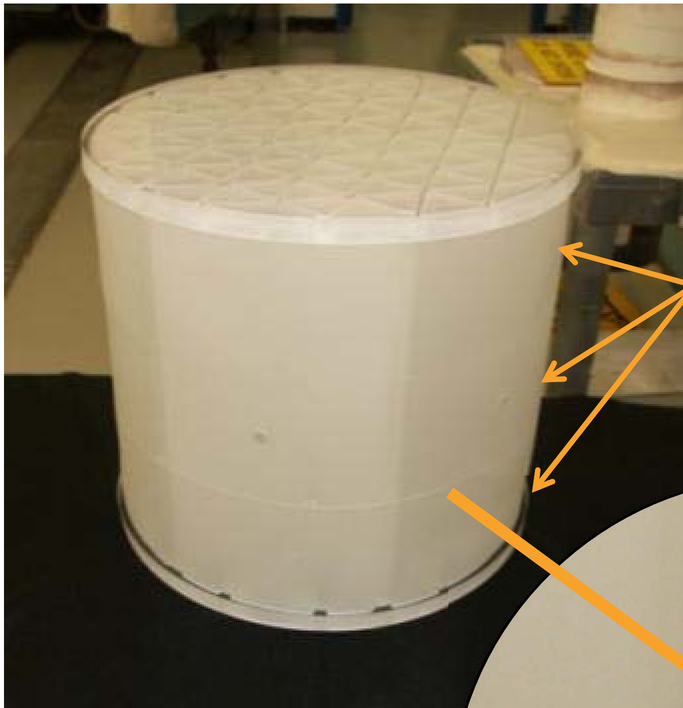
Deep AWJ Cutting

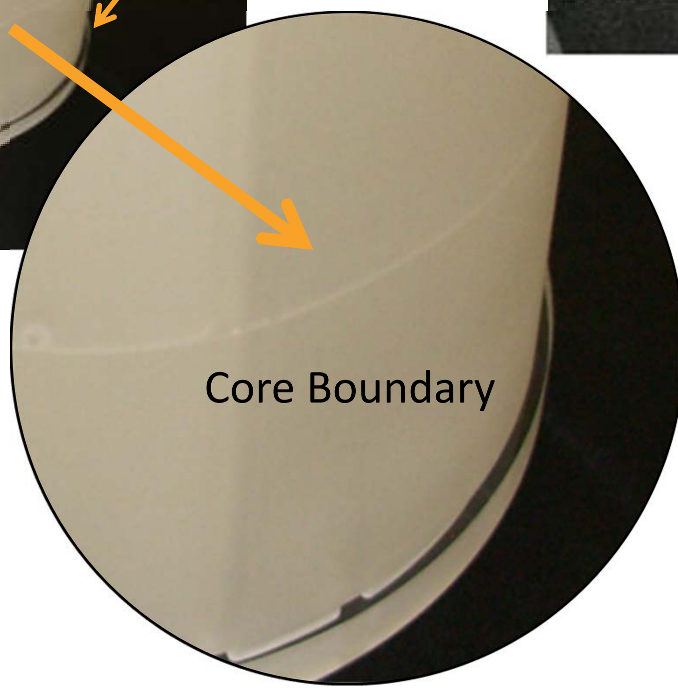
- > Extend AWJ cutting depth for LW cores from current 300mm (11.6 in) up to 480mm (19 in) depending on mirror stiffness
- > More difficult to control exit surface parameters



Stacked Core Mirror Demonstration

0.4m Demonstration part fabricated





Single Mirror Core
(Note large cell size)

- The individual core segment surfaces are polished and AWJ just like traditional LTF mirrors
- During Low Temperature Fusion (LTF), the faceplates **and** the core segments are fused together (Co-Fired)

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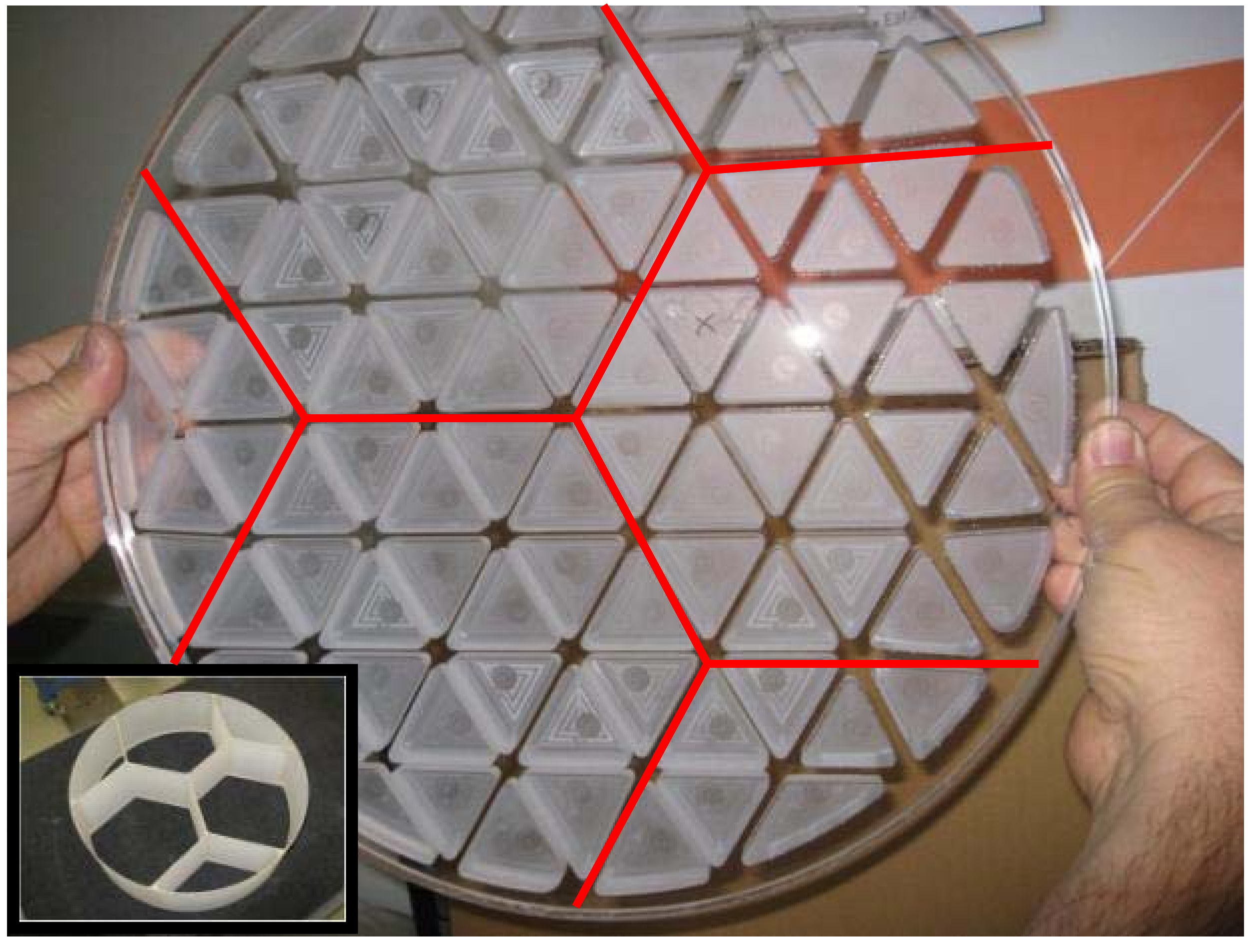
Faceplate Pocket Milling

- Pocket milled facesheets have been used on other mirrors to provide additional stiffness between cell supports
- Allow for much larger core cell size to reduce overall areal density
- Extended to 24 pockets to enhance UV performance

Pocket Milled Facesheet



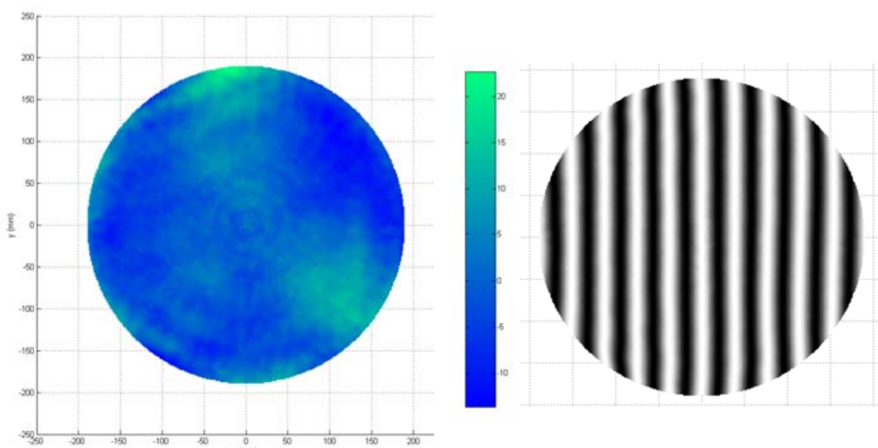
Pocket Milled Facesheet
Core cells locations shown in red
(Core shown for reference)

Processing Quality

Processing completed to demonstrate that UV quality (5nm RMS) could be achieved

Multiple orientation test minimized test errors and analytical backouts

- Some minimal trefoil did not cancel out during testing
- Mount repeatability ultimately limited final performance

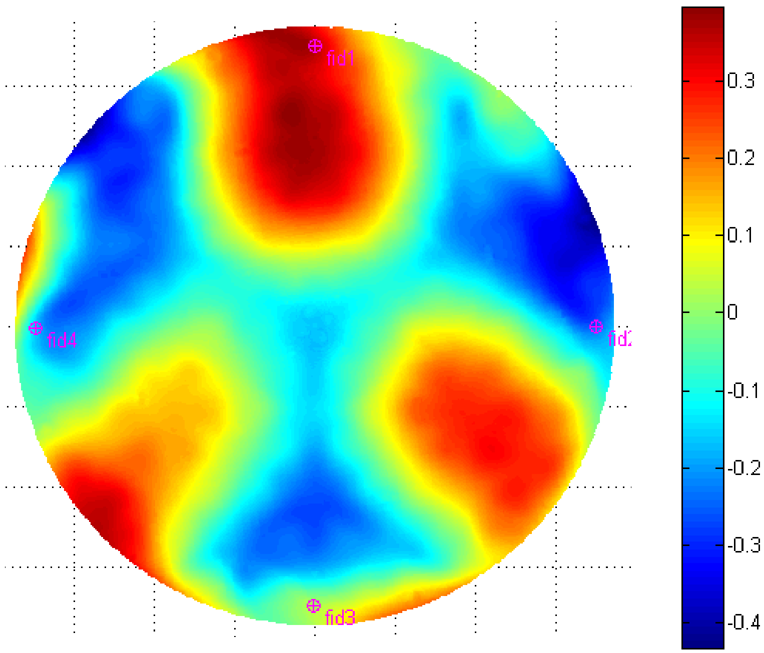


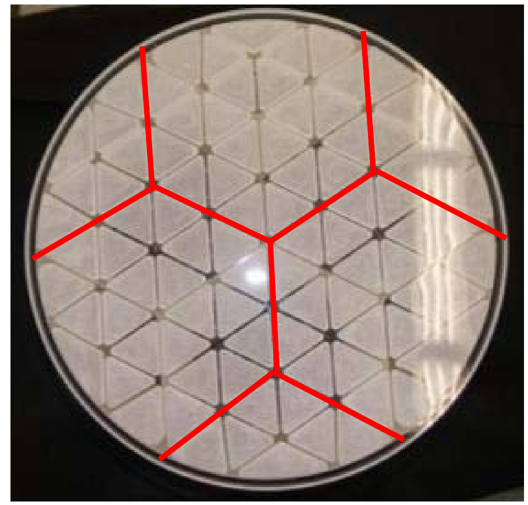
Final Optical Test – 5.5nm RMS

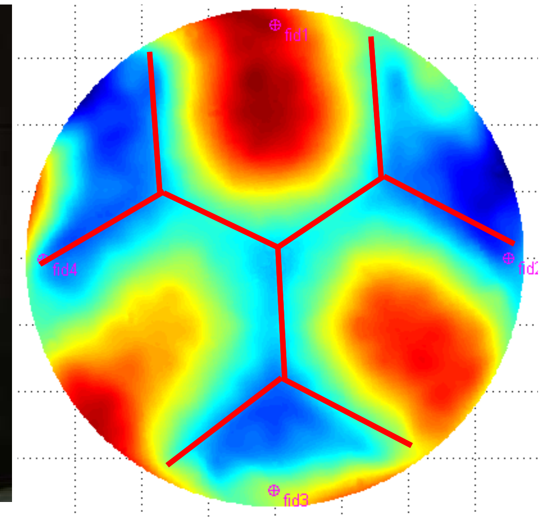
Demo Part in V-Block for Horizontal Testing

First Light Test

117nm RMS – 524nm P-V
Power Removed



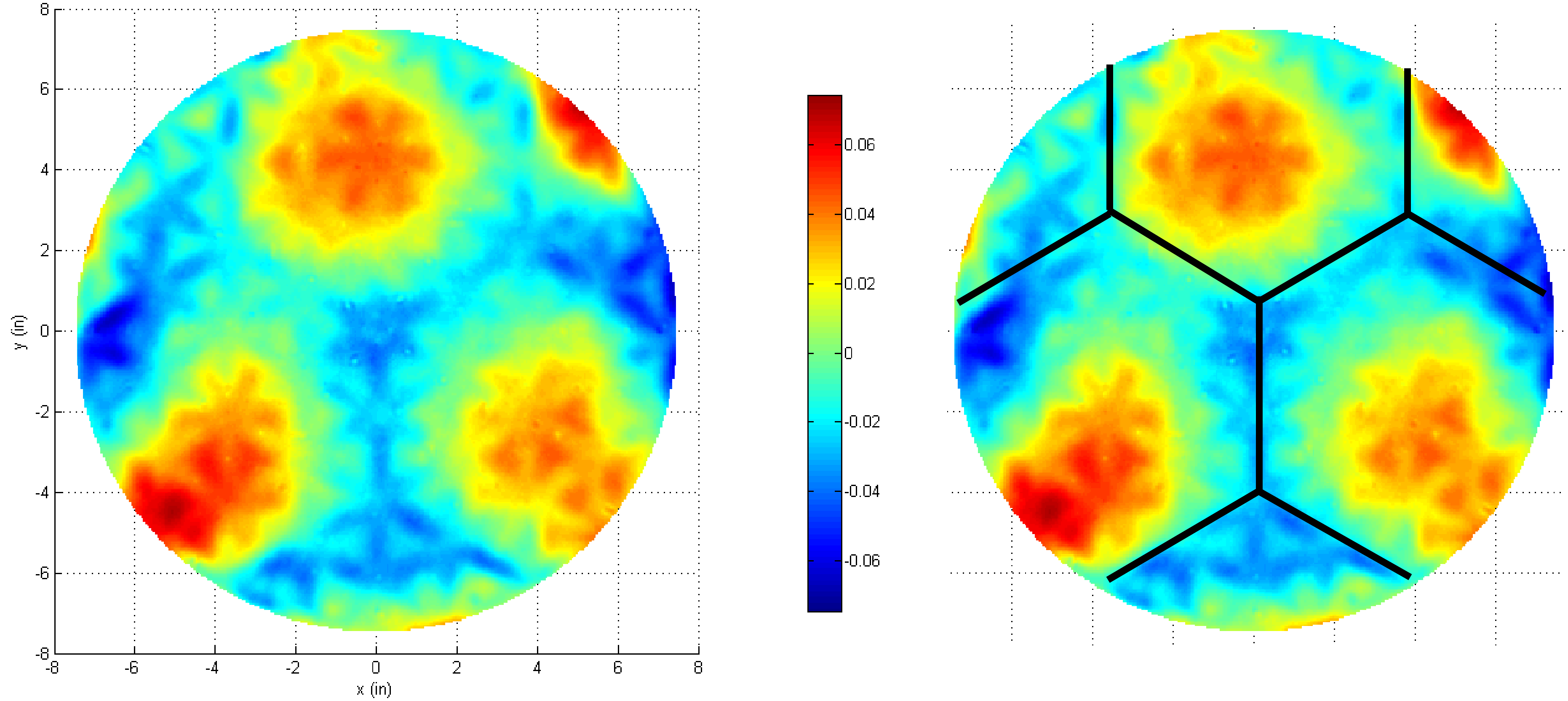




Global polishing quilting over the large cells is observed after initial polishing

Post Ion Figuring #1

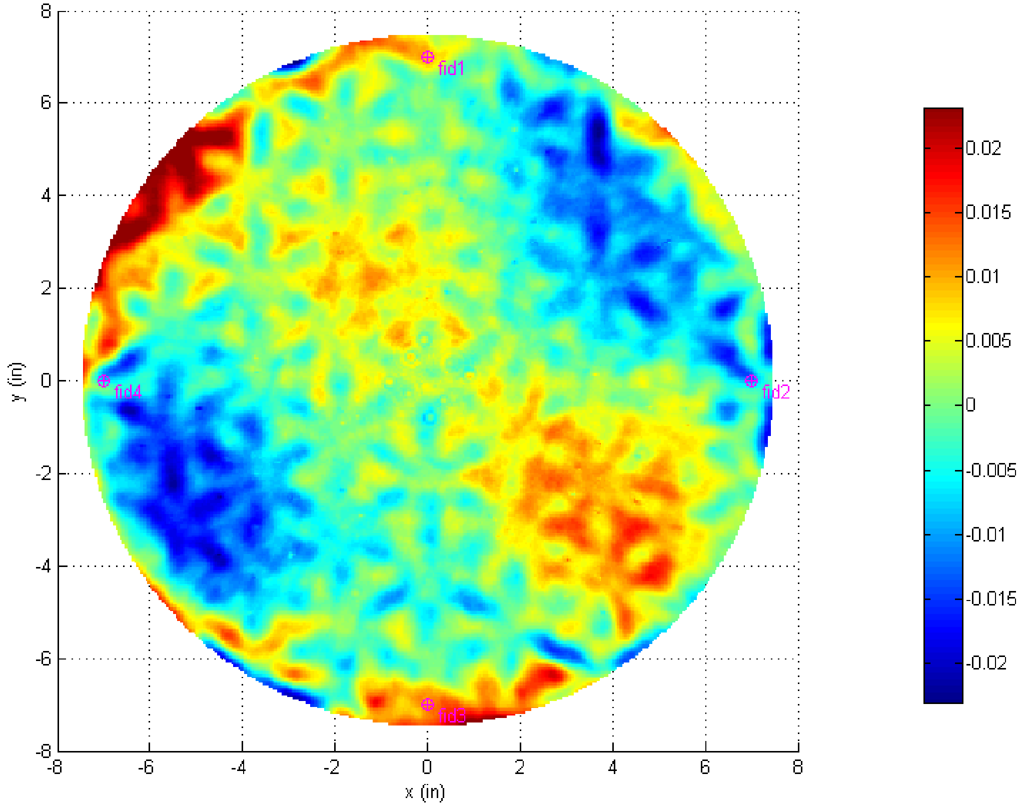
16nm RMS – 87nm P-V
Power Removed

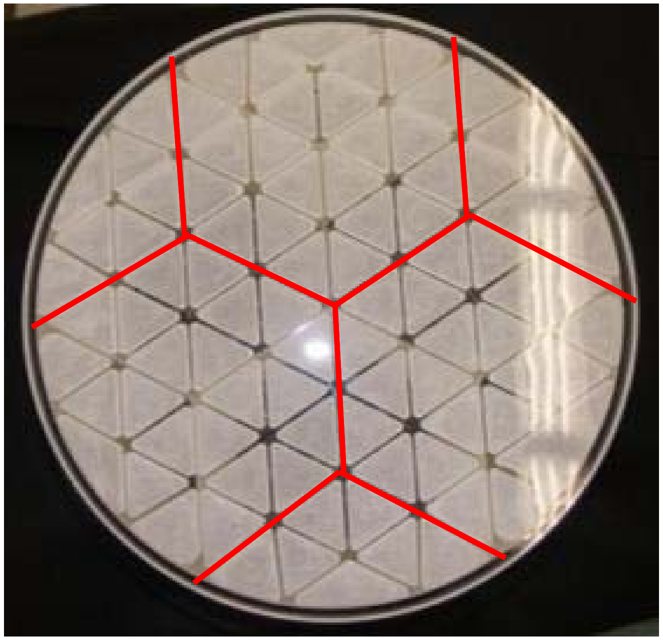


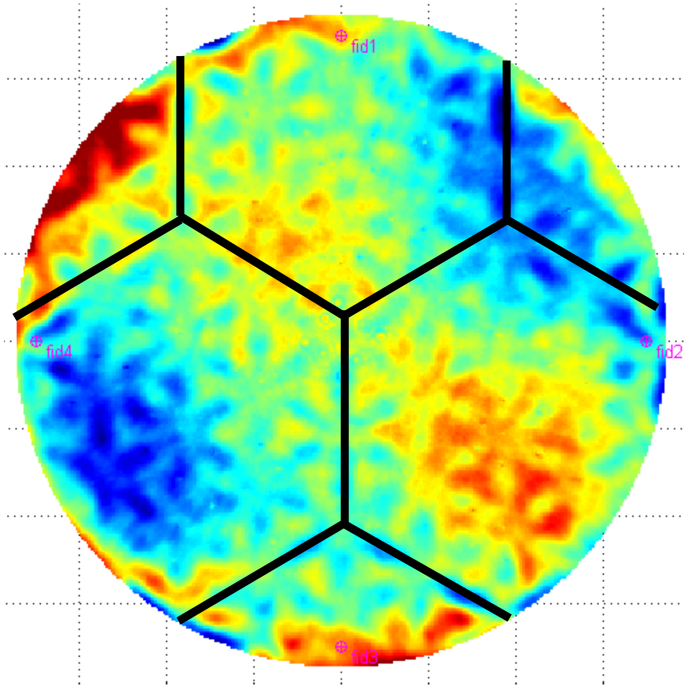
- First ion cycle greatly reduced the global figure error by 86%.
- Some cell quilting still visible

Post Ion Figuring #2

4.9nm RMS – 37nm P-V
Power Removed





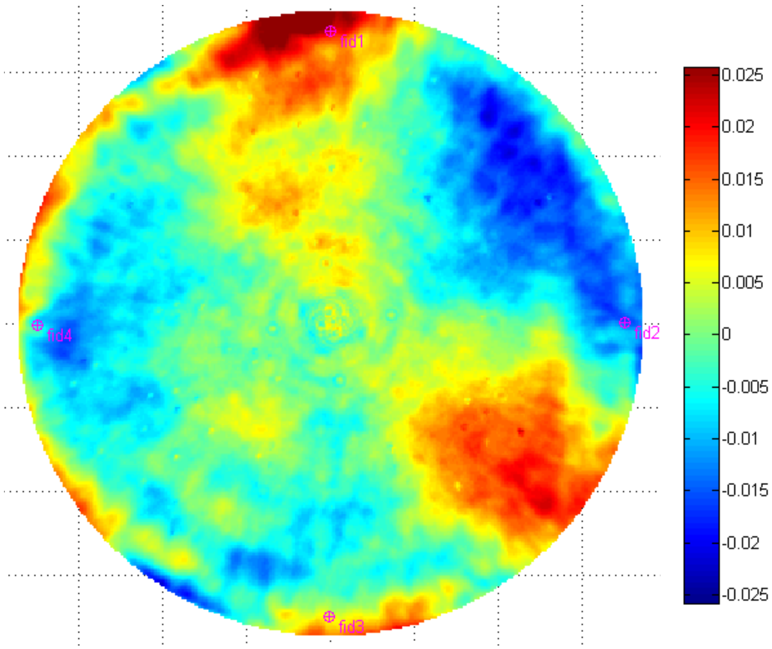


- Second ion cycle further reduced the errors by an additional 68%
- Pocket milled quilting becomes visible

EXELIS

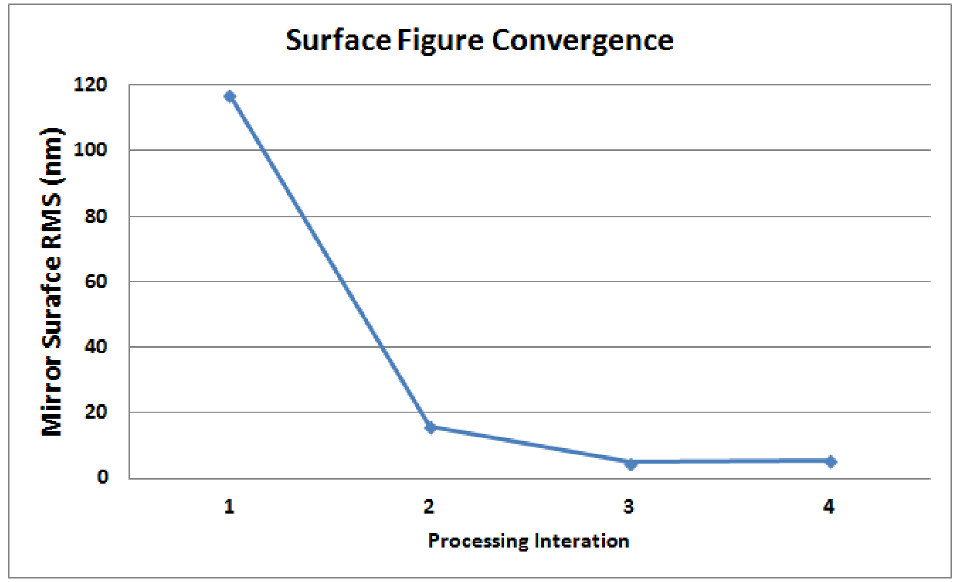
Post Ion Figuring #3

5.4nm RMS – 37nm P-V
Power Removed

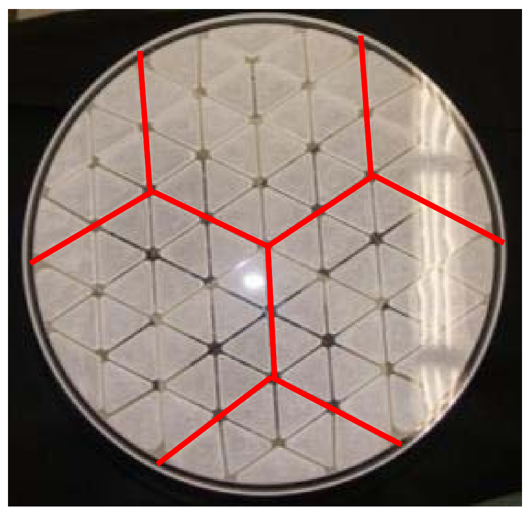


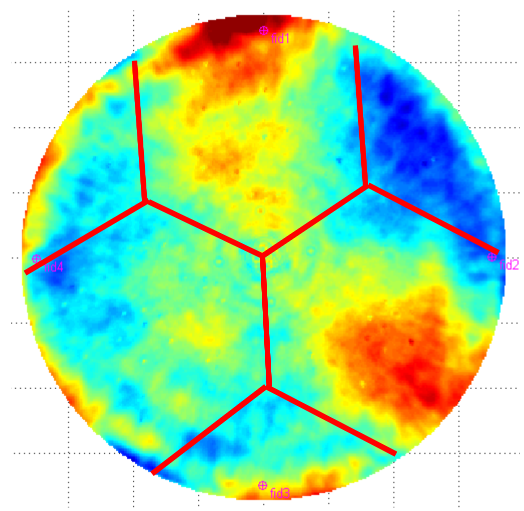
- Final ion figuring run reduces pocket quilting
- Mount repeatability limits overall surface quality

EXELIS



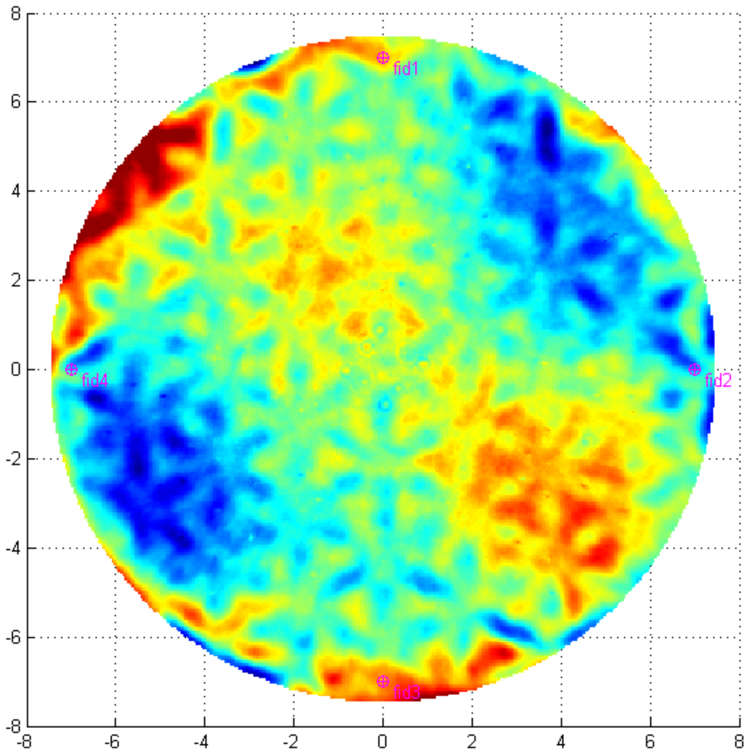
- Rapid convergence to final surface quality
- Deterministic processes reduce schedule time



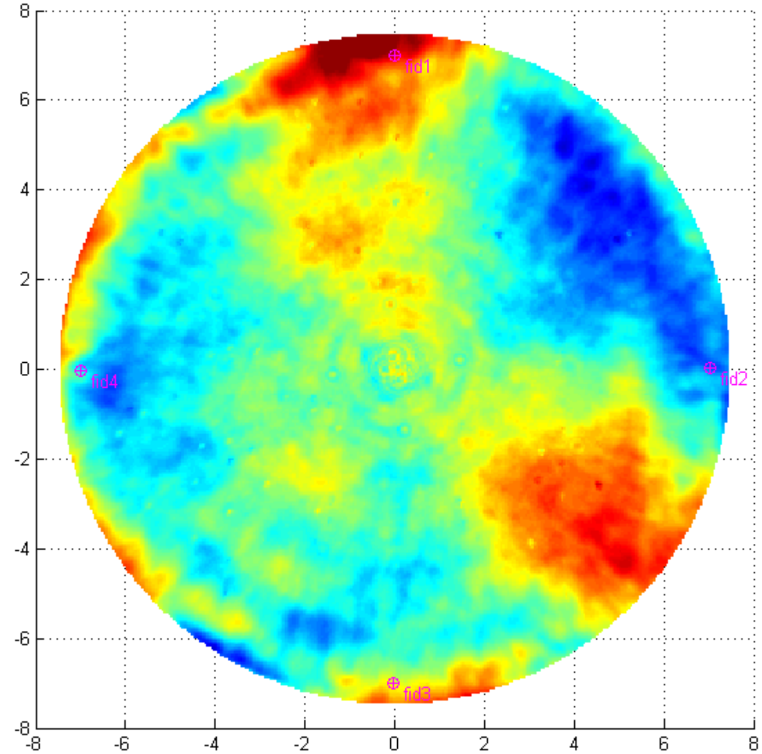


AMTD PSD Testing Summary

- Data collected using Zygo Verifire and White Light Interferometer
- Results show no significant PSD change due to ion figuring in spatial periods smaller than 20mm.



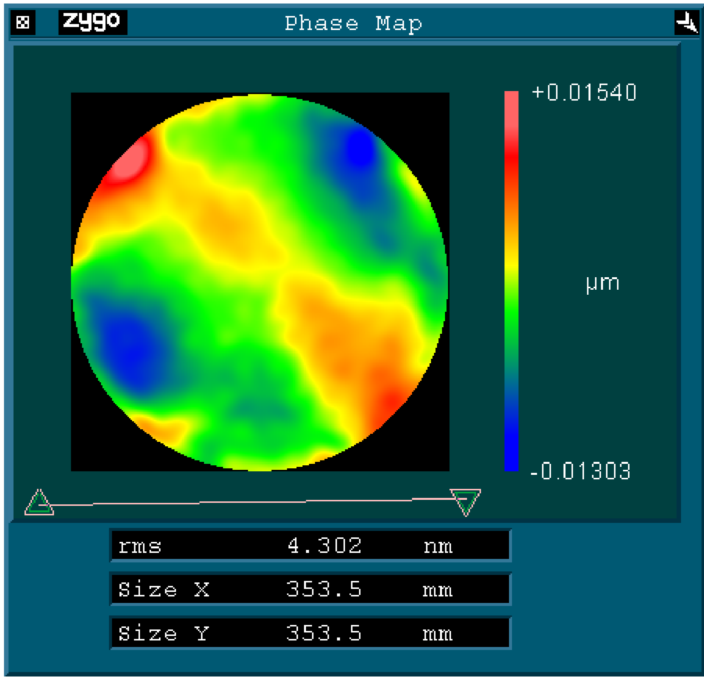
Polishing Quilting



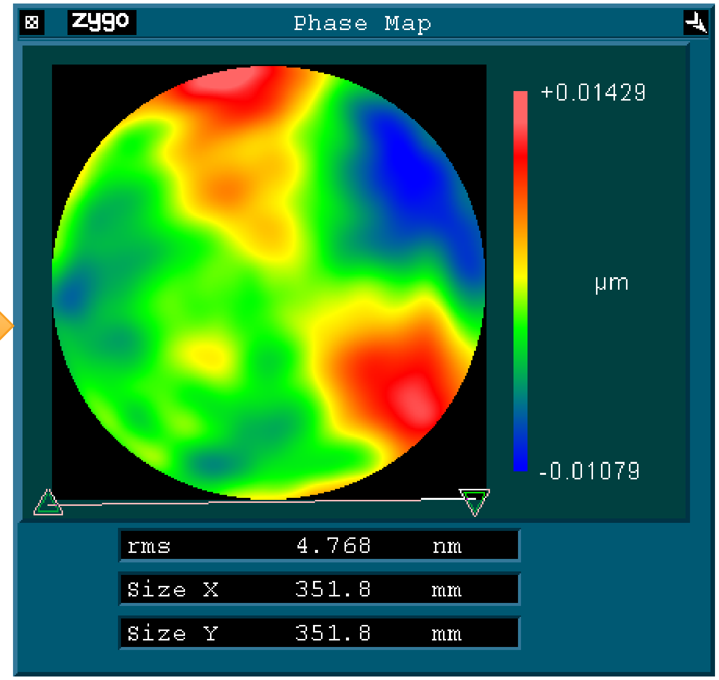
Finished

50mm FFT Low Pass Filter

Before Ion Figuring



After Ion Figuring



> Low order figure error has reached the current metrology reproducibility limit in the current configuration leading to no improvement in figure errors with spatial periods longer than 50mm

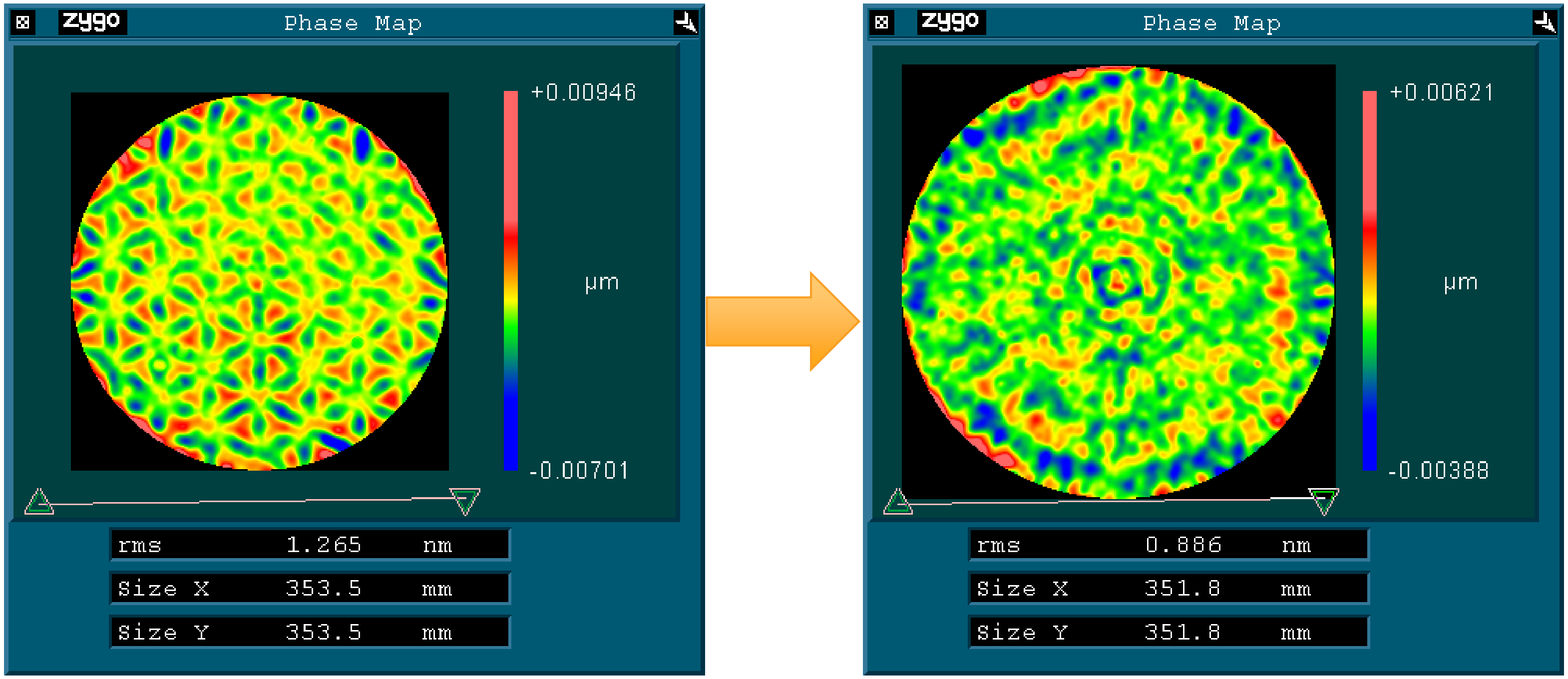
> Low order figure error present in the measurement after ion figuring is driven by mount reproducibility

> Metrology reproducibility and accuracy could be improved with optimize mount design and additional part rotations

50mm-10mm FFT Band Pass Filter

Before Ion Figuring

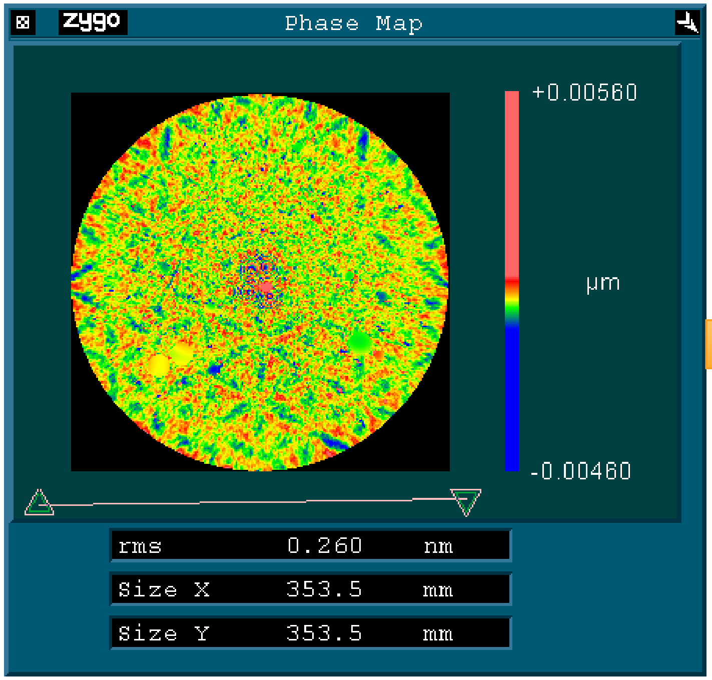
After Ion Figuring



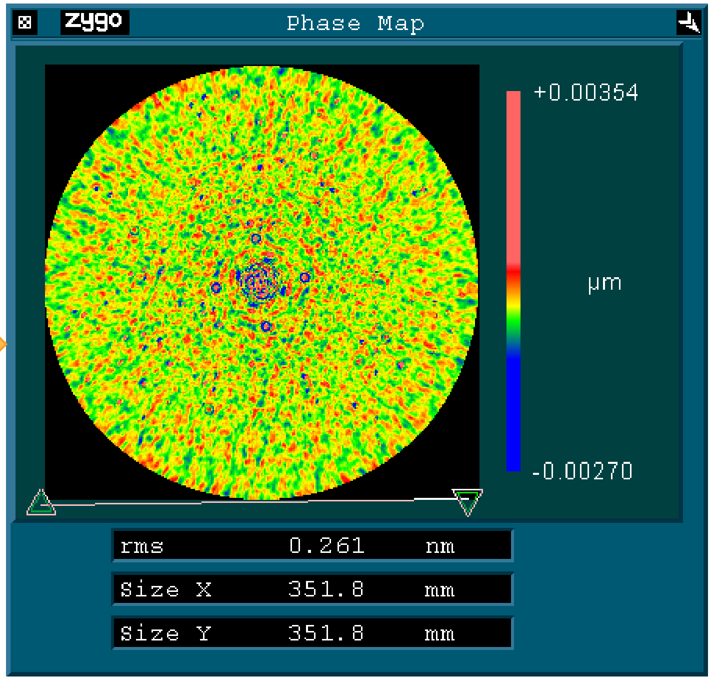
- The quilting period appears at ~30mm spatial periods before ion figuring
- Ion figuring improved the rms in the 50-10mm spatial period band eliminating most of the quilting structure

10mm FFT High Pass Filter

Before Ion Figuring



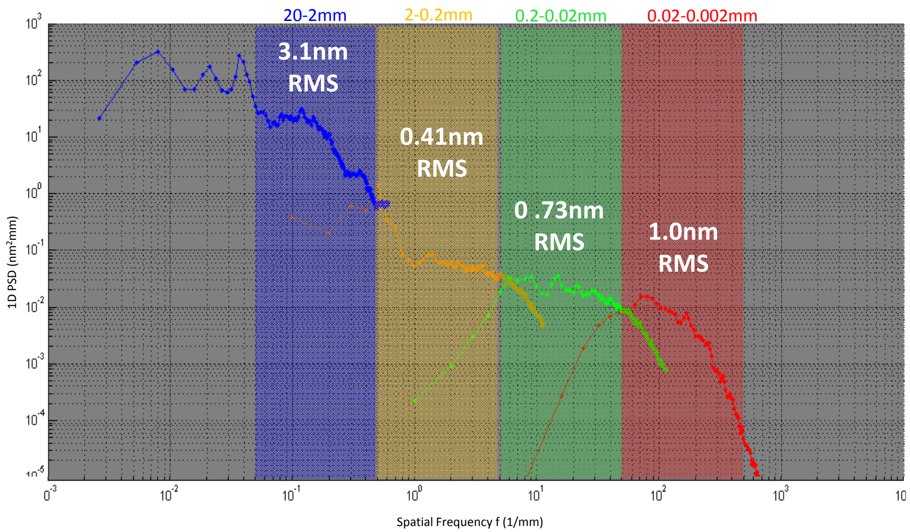
After Ion Figuring



> The shorter spatial periods, <10mm, were negligibly affected by ion figuring

MSFC sphere tested on 12/3/12- PSD (Post Polish)

Before Ion Figuring



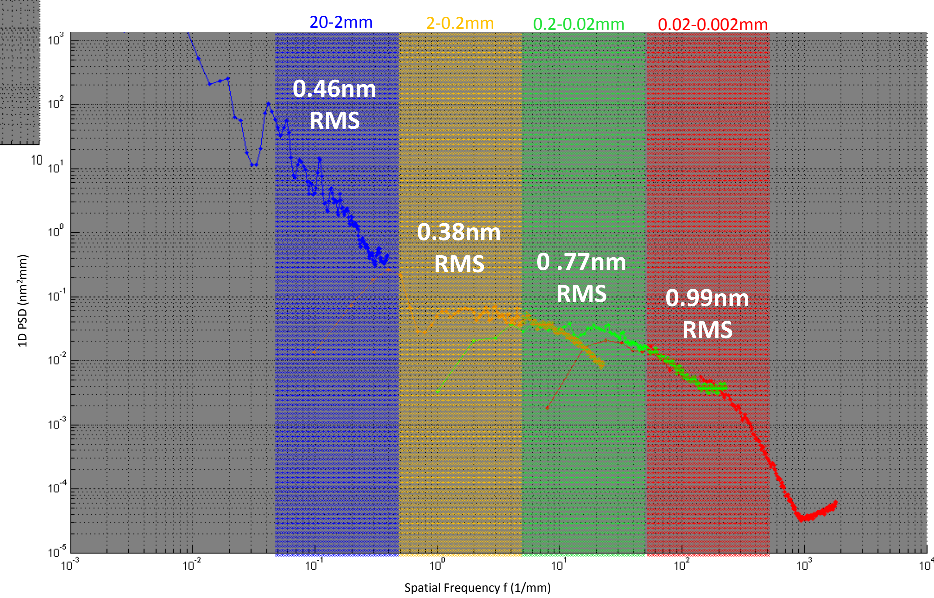
- Zygo Verifire
- Full Aperutre

- Zygo NewView
- 5X Objective; 1X relay
- 1 mm aperture; 2um pixel

- Zygo NewView
- 1X Objective; 0.5X relay
- 10 mm aperture; 22um pixel

- Zygo NewView
- 20X Objective; 2X relay
- 0.13mm aperture; 0.23um pixel

After Ion Figuring



> Bands were analyzed at >5X above Nyquist limit with ~5 cycles per test aperture

> Hanning window used for PSD analysis with magnitude re-scale

> Spatial periods smaller than 20mm were negligibly affected by ion figuring as evident in the PSD plot

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AMTD Testing Summary

- Processing of the stacked core mirror converged very quickly using ion figuring
- Results show no significant PSD change due to ion figuring in spatial periods smaller than 20mm.
- Global surface figure limited by mount repeatability

- All work performed under NASA contract XXXXXXXX
  - COTR: Michael R. Effinger
- Related Papers at this conference
  - Cryogenic optical performance of a lightweighted mirror assembly for future space astronomical telescopes: optical test results and thermal optical model (8837-11)
  - The development of stacked core technology for the fabrication of deep lightweight UV-quality space mirrors (8838-23)